



Controlled Temperature Heat Exchanger for Cryogenic Transfer Lines

W. Boroski, R. Kunzelman, M. Ruschman, and C. Schoo

*Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510*

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INTRODUCTION

The need to provide a constant temperature cooling gas in a cryogenic research laboratory has led to the evolution of a controlled-temperature transfer line heat exchanger. Early attempts to achieve a supply gas of constant temperature from a 500 liter storage dewar consisted of positioning a conventional helium transfer line stinger approximately one inch above the liquid in the bath. By maintaining the dewar at a constant pressure, the gas exiting the dewar was at a constant flow rate. Also, due to stratification in the helium dewar, the temperature of the gas entering the transfer line remained constant. However, as the liquid level decreased, the region of gas at the desired temperature moved lower into the dewar. This resulted in warmer gas entering the transfer line even though the flow rate remained constant. To compensate for the liquid level loss, the transfer line had to be manually lowered further into the dewar to stay within the desired temperature region above the liquid bath. As small inlet temperature fluctuations significantly affected the outlet temperature, this operation had to be performed often, which meant the constant attention of a lab technician.

When installed in a 500 liter helium storage dewar, the controlled-temperature heat exchanger described herein provides a steady stream of cold gas at a constant temperature by controlling the temperature of the exhaust gas exiting the dewar. Designed to accept conventional helium transfer line stingers, the heat exchanger fixes the position of the stinger in the dewar. The device is capable of varying the temperature of the exhaust through a combination of two methods: 1) varying the internal pressure of the storage dewar thereby varying the flow rate through the device; or 2) powering a resistance heater which is integrated into the heat exchanger itself to change the temperature of the exhaust gas.

Use of the heat exchanger device has shown the device capable of providing a constant temperature exhaust gas in the region 10K to 50K. The device eliminates the need for continual personnel attention, which results in an increase in operation efficiency. Furthermore, it has been observed that slower flow rates are needed when using the heat exchanger as compared to high flow rates necessary through the transfer line only; this decrease in flow rate equates to a decreased consumption rate for a more efficient use of the helium.

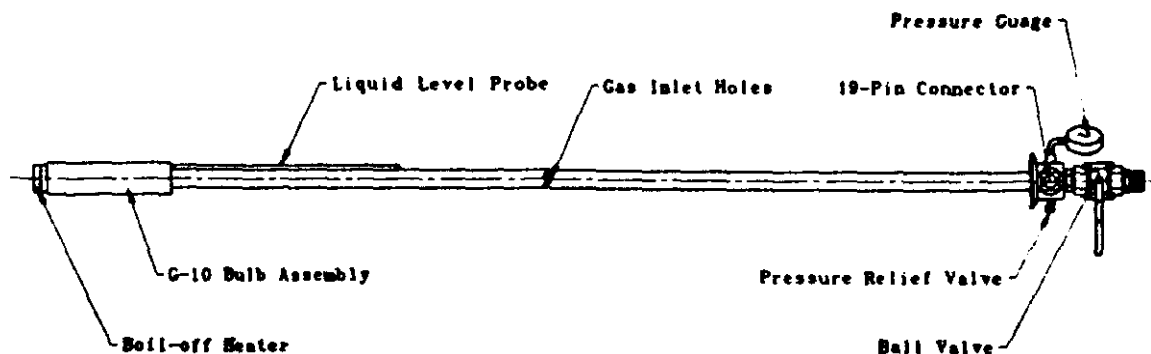


Fig. 1. Controlled-temperature heat exchanger for cryogenic transfer lines

DESCRIPTION OF THE TRANSFER LINE HEAT EXCHANGER

The controlled-temperature heat exchanger, shown in Figure 1, consists of a long cylindrical tube with a valve assembly at the warm end and a bulb assembly at the cold end. The 2.54 cm. thin-wall tube is comprised of glass-epoxy reinforced plastic (GRP) of low thermal conductivity whose length positions the bottom of the bulb assembly one inch from the bottom of a 500 liter storage dewar. Vent holes in the tube allow boil-off gas from the dewar to enter the tube and descend to the bulb assembly; the holes are positioned such that they are always above the liquid level. A commercially-available helium liquid level probe mounted along the tube immediately above the bulb provides information on the liquid level in the dewar during operation.

The bulb assembly, illustrated in Figure 2, consists of a short length of GRP tube whose diameter is slightly greater than the main tube. The bulb houses a cylindrical heat exchanger comprised of a large number of thin copper fins which provide a large surface area through which the vent gas must pass. A resistance heater is thermally-anchored to the heat exchanger and provides the means of varying the temperature of the exit gas. The heater is coiled around the heat exchanger to provide good thermal transfer along the entire heater length. Temperature of the vent gas exiting the device is measured by a precision cryogenic thermometer located near the transfer line inlet. The thermometer is suspended in the gas stream so that the temperature measured is that of the gas and not of the heat exchanger or bulb.

A resistance heater mounted on the outside of the bulb assembly is used to control the amount of boil-off gas generated in the dewar. The heater is mounted on a thin-wall GRP cylinder that is in poor thermal contact with the bottom of the heat exchanger bulb. Varying the power into the heater varies the boil-off rate in the dewar, which varies the flow rate of gas exiting through the transfer line.

The top portion of the transfer line heat exchanger is illustrated in Figure 3. The transfer line stinger is inserted through a ball valve equipped with Teflon seals to maintain a leak-tight seal at low temperatures. Internal pressure of the storage dewar is monitored with a 0-5 psig pressure gauge installed on the top housing. Maximum pressure in the dewar is determined by a self-sealing pressure relief valve that is set to relieve at 3.0 psig; operating experience has shown this to be the preferred pressure for the present test system geometry. Finally, a hermetically-sealed pin connector is used to bring out the instrumentation wires associated with the heat exchanger. These include lead-wires for the two internal heaters, the precision cryogenic thermometer, and the liquid level probe.

OPERATION OF THE TRANSFER LINE HEAT EXCHANGER

The transfer line heat exchanger is installed in a commercial 500 liter storage dewar before transfer operations begin. For safety, the dewar must be stable with an internal pressure not exceeding 0.5 psig. Also, it is imperative that appropriate personal protective equipment (PPE) be utilized during all operations. To install the device, the standard cover of the helium dewar vent is removed and the transfer line heat exchanger slowly inserted into the liquid bath in one continuous operation. The device is designed so as not to interfere with existing relief valves on the storage dewar, thereby maintaining the safety designed into the dewar by the manufacturer. The device as installed is shown in Figure 4.

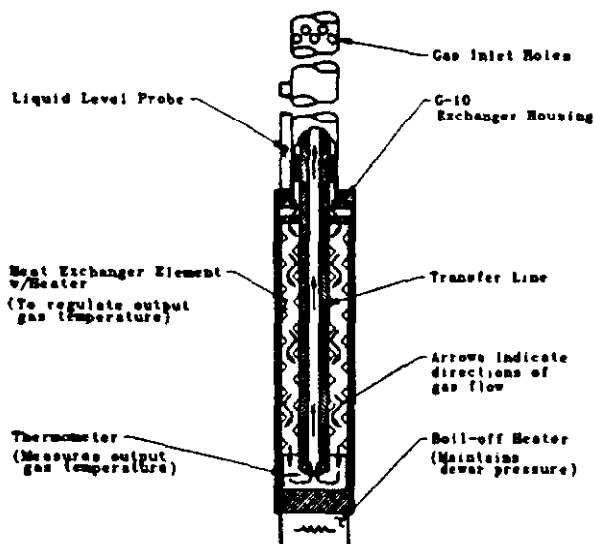


Fig. 2. Heat exchanger bulb assembly

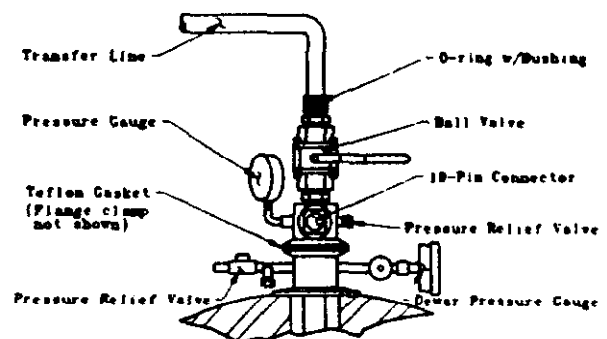


Fig. 3. Heat exchanger valve assembly

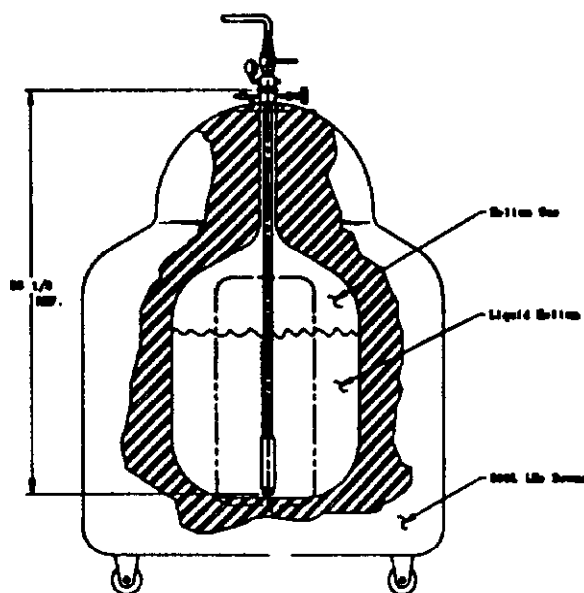


Fig. 4. Heat exchanger installed in 500 L dewar

After the transfer line heat exchanger assembly is installed, the transfer line stinger is inserted into the heat exchanger following commonly-practiced procedures for inserting a stinger into a helium dewar. The stinger length should be such that it extends to within 0.5 inches of the bulb bottom; this positions the inlet of the stinger in the coldest gas region. At this point the transfer line valve should be closed to impede gas flow.

With the transfer line in place, the 0.5 psig relief valve on the dewar is closed to allow pressure in the dewar to build to approximately 3.0 psig. The relief valve on the heat exchanger assembly is set to relieve at this pressure in order to avoid over-pressurization. It should be noted that, provided the heat exchanger is installed slowly into the bath, the pressure rise is at a slow and constant rate and does not pose a danger due to rapid pressure rise.

Once pressure in the dewar reaches the desired level, the transfer line valve is opened to begin gas flow. Cold gas from the dewar enters the heat exchanger through vent holes in the extension tube. Since the dewar vent is now through the transfer line at the bottom of the tube, the gas begins to descend into the bulb of the device. Cooling of the gas occurs as the gas flows through the tube due to the liquid helium in contact with the walls of the tube. This cooling causes some condensation of the gas as it flows through the tube; however, this condensation is flashed back to a gas as a small current is applied to the heater encompassing the

heat exchanger assembly. Subsequently, a pocket of gas exists at the mouth of the transfer line that is of constant temperature; varying the power applied to the heater varies the temperature of this gas. As long as the level of the helium bath in the dewar remains above the bulb assembly, the temperature of the gas pocket remains constant. Hence, the transfer line is always located in a constant temperature gas pocket.

LABORATORY OPERATING EXPERIENCE

A transfer line heat exchanger has been fabricated and tested at Fermilab. The device has proven easy to use and has had a significant impact on the operations of a cryogenic heat leak measurement facility. With the pressure in the storage dewar established, the system operates relatively unattended; an occasional inspection to assure that pressures and temperatures remain constant is all that is required. This has meant the availability of a technician to perform other duties. Additionally, the ability to operate unattended has permitted overnight operations to occur without the need for constant personnel attention on off-hour shifts.

SUMMARY

A transfer line heat exchanger has been designed, built, and placed into operation at Fermilab. The implementation of the device has produced a twofold reduction in operating costs in that unattended operation of the facility is achieved while a decrease in operating cost is realized through a reduction in helium consumption.

The assembly is designed to adapt to cryogenic components commonly found in research environments, and is practical in any situation that requires a controlled temperature gas in the temperature region between 10K and 50K. Temperature control above 50K is most likely, although the upper temperature limit has not been experimentally defined.

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